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HYDROSEEDING ON ANTHRACITE COAL-MINE SPOILS

Abstract.—A study was made of the performance of selected species of legumes, grasses, and trees hydroseeded on anthracite coal-mine spoils in a slurry of lime, fertilizer, and mulch. Hydroseeding failed on coal-breaker refuse, but was partially successful on strip-mine spoils.

How can trees and herbaceous vegetation be established quickly on large areas of anthracite coal-mine spoils in Pennsylvania? It is extremely difficult to establish plants on these sites. Hand-planting works, but is slow. Conventional direct-seeding machinery cannot negotiate the steep slopes and rocky spoils that are typical of mine spoils. But in recent years, one method of direct seeding by machine—hydroseeding—has been used successfully to establish cover on some steep problem areas.

Until now, no formal studies have been made to evaluate the success of hydroseeding various tree and herbaceous species and seeding mixtures on coal-mine spoils, although hydroseeders have been used to revegetate mine spoils in Kentucky and West Virginia. This is a report on such a study conducted by the Forest Service in cooperation with the Pennsylvania Power and Light Co. on the anthracite coal-mine spoils of Pennsylvania.[1]

A hydroseeder consists of a tank, a pump, and a nozzle mounted like a gun. (fig. 1). Seed, fertilizer, lime, and mulch are mixed with water in the tank, and the entire mixture is sprayed directly from the nozzle

[1]Stephen Postupack provided necessary field assistance in this study.

Figure 1.—Hydroseeder in operation.

onto the area to be seeded. The hydroseeder can be mounted on a truck or on a trailer to be pulled by a tractor.

The Study

In April 1967, seeds of trees, grasses, and legumes — mixed in a slurry containing hydrated lime, fertilizer, and wood-fiber mulch — were hydroseeded on coal-mine spoils in the Anthracite Region of Pennsylvania. Two seed mixtures, each containing seeds of a coniferous and a hardwood tree species, a legume, and a grass, were hydroseeded on separate plots. The plot layout included two spoil materials, each with two grading conditions, and two seed mixtures, each replicated four times. Thus 32 plots were hydroseeded. Each plot was 33 by 33 feet square, plus a 3-foot buffer strip on each side.

The study sites were chosen in the southern coal field near Tamaqua and Lansford boroughs on lands owned by the Greenwood Stripping Company.

Site.—Two coal mine spoils, a strip-mine spoil and a coal-breaker refuse, each represented in the graded and ungraded condition, were

Table 1.—*Selected characteristics of experimental sites*

[Average of four replications]

Spoil type	Coarse fraction	Soil-size fraction			pH	Lime requirement
		Sand	Silt	Clay		
	Pct.	*Pct.*	*Pct.*	*Pct.*		*Tons/acre*
Strip-mine:						
Graded	46	23	16	15	4.8	2.9
Ungraded	66	15	10	9	4.5	3.2
Breaker refuse:						
Graded	63	24	11	2	3.8	3.8
Ungraded	70	20	8	2	3.7	3.8

selected as experimental sites. The ungraded sites included two aspects, northeastern and southwestern, and had slopes of about 40 degrees. The graded sites were on almost level ground, except two plots on a slope of about 7 degrees of northern aspect.

After the plots were delineated, bulk samples were taken to a depth of 6 inches for determination of the physical make up, pH values, and lime requirement (table 1).

The strip-mine spoils resembled the material described earlier[2] as sandstone and conglomerates, type III. The spoils consisted of sandstone rocks over 2 inches in diameter (discarded from analysis), fragments from 2 inches to 2 mm. in diameter, and particles less than 2 mm. (referred to here as the soil-size fraction). The graded sites had lower rock content and a much higher content of gray shales than the ungraded sites, thus the graded sites had more soil-size material (table 1).

The coal-breaker refuse — a black material separated from the coal during the process of coal cleaning — consisted of a loose mixture of fragments of carbonaceous slaty shale, medium-size coal pieces, and a soil-size fraction. Because of the oxidation of pyrites released from weathered shale fragments, the materials were highly acid. The characteristics of coal-breaker refuse as a plant growth media were described earlier.[3] The sites selected had high proportions of coarse fraction — 63 percent in graded sites and 70 percent in ungraded sites — and extremely

[2]Czapowskyj, Miroslaw M.—Experimental Planting of 14 Tree Species on Pennsylvania's Anthracite Strip-mine Spoils. USDA Forest Serv. Res. Paper NE-155, 18 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa. 1970.

[3]Czapowskyj, Miroslaw M.—Performance of Red Pine and Japanese Larch Planted on Anthracite Coal-breaker Refuse. Proc. Int. Symp. Drastically Disturbed Lands. Manuscript in preparation. NE. Forest Exp. Sta. 1969.

low amounts of clay-sized fraction — 2 percent in both (table 1). The acidity before hydroseeding was too high for plant survival and normal growth.

Hydroseeding.—The hydroseeder — manufactured by the Finn Co.[4] in Ohio — had a 500-gallon tank, an agitator, pumps, and spraying hoses and nozzles. In preparing the slurry, the tank was first partly filled with water. Then, with the agitator operating, the prescribed quantities of lime, fertilizer, and wood-fiber mulch[5] were added and mixed for at least 20 minutes. The tank was filled to capacity with water. The seed mixture (table 2) was added to the agitated slurry.

Lime was added in the amount necessary — based on the analysis of the spoil samples (table 1) — to bring pH on all plots to 6.0, or slightly above in the top 6 inches. Fertilizer was added at a level considered adequate for a site of low fertility. Wood-fiber mulch was applied at the rate recommended by the manufacturer.

[4]Mention of a particular product should not be taken as endorsement by the Forest Service or the U. S. Department of Agriculture.
[5]Silva-Fiber (Weyerhaeuser Co.).

Table 2.—*Seed mixtures and amount of seeds used (in grams)*

Species	Per tank load	Per plot*	Per acre
		MIXTURE A	
Red pine *Pinus resinosa* L.	56	28	940
Gray birch *Betula populifolia* Marsh	56	28	940
Perennial ryegrass *Lolium perenne* L.	262	131	4,402
Sericea lespedeza *Lespedeza cuneata* (Dumont) G. Don	376	188	6,318
Total	750	375	12,600
		MIXTURE B	
Scotch pine *P. sylvestris* L.	56	28	940
Black locust *Robinia pseudocacia* L.	56	28	940
Tall fescue Ky. 31 *Festuca arundinacea* Schreb.	262	131	4,402
Penngift crownvetch *Coronilla varia* L.	376	188	6,318
Total	750	375	12,600

*Includes 3-foot buffer strip.

The composition of the slurry (in pounds) was as follows:

Amendment	*Per tank load*	*Per plot*	*Per acre*
Hydrated lime	312.0	156.0	5,250
Fertilizer (10-10-10)	25.0	12.5	420
Silva-Fiber Mulch	125.0	62.5	2,100

The data for the plots do not include the buffer strip. The hydrated lime data are 100 percent calcium carbonate equivalent.

Water for the slurry was from a public water supply at a nearby colliery. The slurry was agitated continuously during the trip to the plots.

One tank load of the slurry was used to hydroseed two plots. The slurry was sprayed as evenly as possible on each plot and buffer strip. About 8 minutes were needed to hydroseed one plot. Appropriate legume inoculant was spread manually immediately. About 1½ hours were needed from the start of slurry preparation to completion of a cycle.

After the first seed mixture was sprayed (eight loads), the tank was drained and washed of residues.

Collection of data.—After the first two growing seasons (1967 and 1968), the number of emerged plants on the graded spoils was determined as follows. A square frame, 2.2 feet on each side, was placed at 18 randomly selected points on each plot, and the emerged trees, legumes, and grasses were counted. The data were converted to number of plants by species per milacre (table 3).

This method could not be used on ungraded spoils, because walking

Table 3.—*Number of plants after the first and second growing seasons on 1-milacre plot on graded spoils*

[Average of four replications]

Species	Strip-mine spoil		Coal-breaker refuse	
	1967	1968	1967	1968
		MIXTURE A		
Red pine	1	2	<1	0
Gray birch	1	7	<1	1
Perennial ryegrass	176	38	7	<1
Sericea lespedeza	176	180	82	115
		MIXTURE B		
Scotch pine	2	1	0	<1
Black locust	1	0	0	0
Tall fescue Ky. 31	307	178	14	8
Penngift crownvetch	95	8	42	22

Table 4.—*Average numerical rating (from 0 to 4) of stand performance per plot on hydroseeded strip-mine spoils*

Species	Ungraded		Graded
	N.E. slope	S.W. slope	
	MIXTURE A		
Red pine	0.5	2.0	1.0
Gray birch	1.0	1.0	1.0
Perennial ryegrass	1.0	0	.5
Sericea lespedeza	4.0	1.0	1.0
	MIXTURE B		
Scotch pine	1.0	0	2.0
Black locust	0	.5	1.0
Tall fescue Ky. 31	3.5	1.5	2.5
Penngift crownvetch	2.5	.5	2.0

on the plots to collect the data would have caused rock sliding and damage to the plots. Germination and plant emergence were observed, but no estimates were attempted.

In the fall of 1969, after the third growing season, it became evident that the counting method would be unsuitable for making comparisons of the relative success of establishment between trees, legumes, and grasses. So, in order to have a more suitable basis for comparing the performance of each species on each spoil, a numerical rating system was used. Three experienced workers independently rated the performance of each species on each plot, and the ratings by all workers for all plants were averaged (table 4). The rating system — based on a set of criteria that took into account such factors as number of plants, plant vigor, and ground cover — was as follows:

Rating	*Number of trees*	*Criteria for legumes and grasses*
0	None	No plants
1	1 to 5	Individual plants, poor growth
2	6 to 12	Occasional clumps, stunted growth
3	13 to 20	Frequent clumps, acceptable growth
4	21 to 50	Adequate cover, good growth

Results and Discussion

Emergence and establishment varied widely between species and between spoils (tables 3 and 4). No plants became established on coal-breaker refuse.

Coal-breaker refuse.—Plots hydroseeded on ungraded breaker refuse showed negligible emergence, and all plants subsequently died.

Plots hydroseeded on graded breaker refuse showed only slightly better emergence. Considerable numbers of sericea lespedeza, Penngift crownvetch, and tall fescue Ky. 31 emerged during the first growing season. Except for sericea lespedeza, which increased in number, these species decreased in number during the second growing season. All species died by the end of the third growing season.

Previous attempts to direct-seed crownvetch on coal-breaker refuse also failed.[6] Attempts to direct-seed other species on these spoils have yielded variable results.[7]

Strip-mine spoils.—The plots hydroseeded on strip-mine spoils performed markedly better. Overall emergence and establishment varied considerably between graded and ungraded sites and between aspects. Some plots produced an adequate stand of at least one species (fig. 2).

Red and Scotch pines emerged poorly, but the seedlings that survived had good vigor. Gray birch and black locust had poor emergence and survival. Gray birch had slightly better emergence than black locust,

[6]Czapowskyj, Miroslaw M., John P. Mikulecky, and Edward A. Sowa. RESPONSE OF CROWNVETCH ON ANTHRACITE BREAKER REFUSE. USDA Forest Serv. Res. Note NE-78, 7 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa. 1968.

[7]Schramm, J. R. PLANT COLONIZATION STUDIES ON BLACK WASTES FROM ANTHRACITE MINING IN PENNSYLVANIA. Trans. Amer. Philos. Soc. New Series, Part 1, 56 pp., illus. 1966.

Figure 2.—Series of hydroseeded plots on northeast aspect of ungraded spoil-type III (sandstone and conglomerate) after 3 years. The plots did not reach to the top of the slope and were separated by unhydroseeded strips. From foreground the plots are, crownvetch, lespedeza and lespedeza.

but gray birch occurred naturally in the area and it may have emerged partly from seed from natural sources.

Crownvetch emerged and grew only in clumps and performed about the same on both graded and ungraded sites. It grew slightly better than sericea lespedeza on graded sites. Only a few plants were found on southwestern slopes.

Sericea lespedeza — which performed best on northeastern slopes, where it produced a stand with adequate ground cover and good growth for the conditions — grew better than crownvetch on ungraded sites.

Tall fescue Ky. 31 performed about as well as sericea lespedeza. It performed better than perennial ryegrass and was healthy, but it provided only spotty ground cover.

Some volunteer plants, apparently from natural local seed sources, were noted on all the plots.

Recommendations and Conclusions

Although this study was limited in scope, and the results presented here apply only to the conditions under which the study was performed, general conclusions and recommendations are made as follows:

- Because neither the trees nor legumes and grasses became established on coal-breaker refuse, we do not recommend any revegetation programs by hydroseeding on similar sites until more research data are available.
- Hydroseeding strip-mine spoils may result only in partial success, but it may be recommended for certain sites. Spoil characteristics — especially slope, aspect, and physical make-up — in addition to species selection, have to be carefully weighed.
- The advantages of hydroseeding in establishing ground cover may be considerable. The results obtained in this study provide a basis for more research on hydroseeding as a direct-seeding method for rapid establishment of ground cover.

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